DEVELOPMENT AND FULL-SCALE DUMMY TESTS OF A POP-UP HOOD SYSTEM FOR PEDESTRIAN PROTECTION

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ABSTRACT

A pop-up hood system has been developed to reduce the severity of head injuries to pedestrians in pedestrian-to-automobile accidents.

The system employs sensors located on the bumper to detect impact with a pedestrian. If an impact occurs, a signal is sent to an actuator to raise the rear portion of the engine hood approximately 100mm. This provides a space between the engine and other hard components and the hood, resulting in reduced pedestrian head injuries.

Previous studies have mainly employed headform impactors to evaluate the head injury criteria (HIC) values for pop-up hoods.

This report describes studies of the effect of the pop-up hood on injury parameters and kinematics using the POLAR pedestrian dummy.
The effectiveness of the pop-up hood system was confirmed by the significant reduction of HIC values in impact tests using the POLAR dummy.

INTRODUCTION

There are approximately 2,300 pedestrian fatalities annually in Japan, accounting for roughly 30% of all traffic fatalities. (1) In the EU this figure is approximately 7,000 fatalities (20%) (2), and in the USA approximately 4,700 fatalities (11%) (3).

The most frequent area of injury, in pedestrian fatalities, is the head in approximately 60% of the cases (2), and the vehicle area causing these injuries most often is the hood. (4) To reduce the number of pedestrian fatalities, countermeasures can be taken to help reduce the severity of head injuries caused by the pedestrian's head impacting the hood.
As means of helping reduce pedestrian head injuries, Honda has adopted impact-absorbing structures in the hood, link type hinges, pyro-actuators and sensors in the front bumper.

Honda has developed a pop-up hood that provides a space in the engine bay by lifting up the hood at the time of collision, thereby helping reduce the severity of a pedestrian's head impact with the hood.

Previous studies of pop-up hoods have reported Head Injury Criteria (HIC) evaluations according to tests using headform impactors. (5)

The purpose of this paper is to evaluate the effect of the hood pop-up action on dummy kinematics and on HIC, using pedestrian dummies (6).
The research includes the following:
1) Calculations of contact time of the pedestrian's head with the hood using a computer simulation

2) Setting the device operation time

3) The pop-up hood system

4) Test confirmation of the deployment time

5) Confirmation of dummy kinematics and injury values, through pedestrian dummy tests

CALCULATIONS OF CONTACT TIME OF THE PEDESTRIAN'S HEAD ON THE HOOD

Figure 1 shows the simulation model. Each part of the dummy model body is expressed as ellipsoid elements. (7) The dummies used were C6Y, AF05, and AM50. The dummies represent pedestrians impacted from the side while crossing a road. The hood edge height in this vehicle model was approximately 670mm.

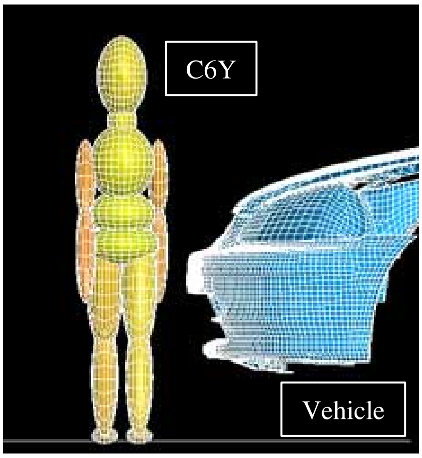

Figure 1. Simulation model of dummy crash.

The impact speed was set at 40km/h, and the location of the impact was the center of the vehicle.

The height of each dummy model and the time to collision of the head with the hood, obtained through the simulations, are given in Table 1.

The shorter the height, the shorter the head contact time with the hood. With C6Y, the contact time was 63ms under this simulation condition.

Table 1.
Dummy's height and head contact time.

	C6Y	AF05	AM50
Height	1.15m	1.52m	1.77m
Head contact time	63ms	97ms	140ms

SETTING THE DEVICE OPERATION TIME

Based on the results of C6Y's simulation, the target device operation time was set at 60ms or less in this study so that the device completes its operation faster than the time between the pedestrian's leg contacting the bumper and the pedestrian's head contacting the hood.

POP-UP HOOD SYSTEM

As shown in Figure 2, the pop-up hood is composed of a sensing system and hood lifting elements.

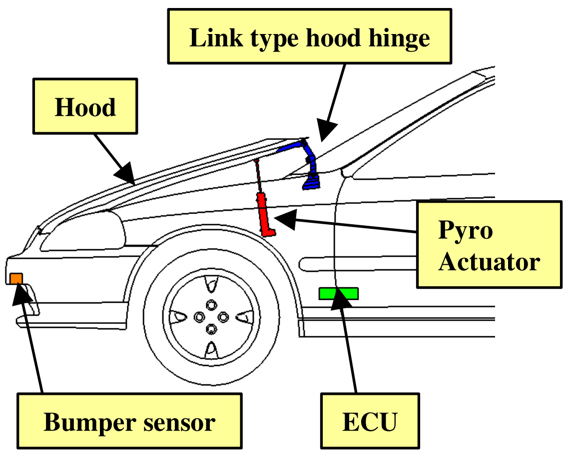

Figure 2. Pop-up hood system.

Sensing System

As shown in Figure 3, sensors are located on the structure in front of the bumper beam, in areas that deform due to collisions with pedestrians.

Accelerometers are used for the bumper sensors. Bumper sensors detect collisions with an object of a weight equivalent to that of a pedestrian.

The ECU located inside the cabin judges the need for device operation, according to collision signals from the bumper sensors, and vehicle speed information.

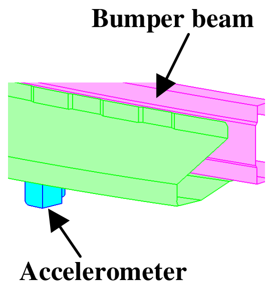

Figure 3. Sensing system.

Hood Lifting Elements

As shown in Figure 2, the hood lifting elements are actuators, hood hinges, and the hood. A pyro-actuator has been adopted so that the hood lifts rapidly. The actuator is composed of a micro gas generator and a shaft, as shown in Figure 4.

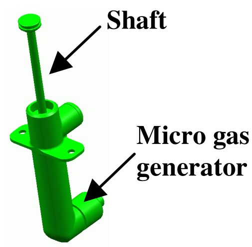

Figure 4. Pyro-Actuator.

The hood hinge adopted is a link type hinge, as shown in Figure 5. The link hinge is composed of an upper bracket, lower bracket, arm A, arm B, three pivots, and a pin.

According to an ignition signal from the ECU, gas from the micro gas generator raises the shaft. The shaft shears the hood hinge pin, lifting the rear portion of the hood approximately 100mm, thereby providing a space between the hood and the hard components under the hood, such as the engine.

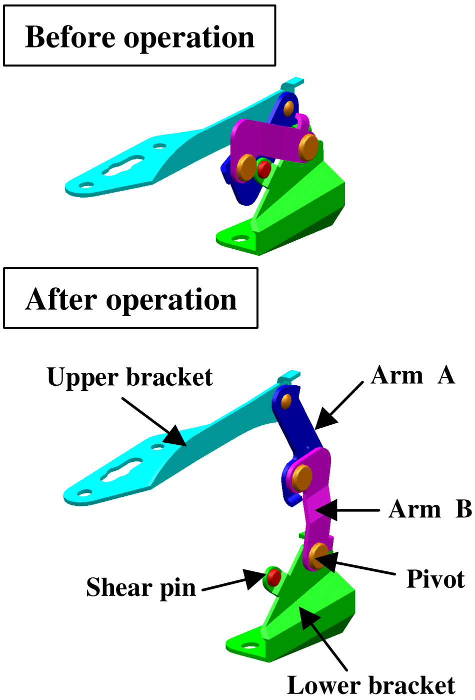

Figure 5. Hood hinge of link type.

TEST CONFIRMATION OF THE DEPLOYMENT TIME

The setup for the hood lift operation testing is given in Figure 6. The actuators were placed near the hood hinges, one each on the left and right sides. The actuators were operated by an ignition signal, and the time until the hood has been lifted 100mm was measured.

Figure 6. Setup for hood lift operation testing.

As the target device operation time was equal or less than 60ms, as noted above, the target deployment time was set at 30ms or less in this study, excluding the sensing time.

Figure 7 gives the test results. With the adoption of the pyro-actuators, a hood lift time of no more than 30ms was confirmed.

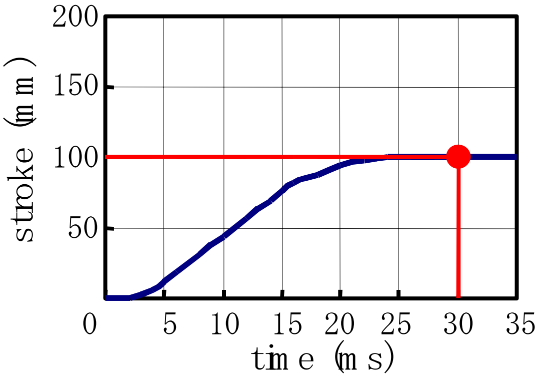

Figure 7. Results of hood lift operation testing.

CONFIRMATION OF DUMMY KINEMATICS AND INJURY VALUES, THROUGH PEDESTRIAN DUMMY TESTS

In order to confirm the effect of the hood lift operation on dummy kinematics and on injury values, impact tests were performed using a pedestrian dummy. The test conditions and setup are shown in Figure 8.

Figure 8. Setup of Pedestrian dummy test.

Tests were conducted both with and without operation of the hood lift device. The pedestrian dummies were set to receive a collision impact from the side. The dummy's arms were in front, and both wrists were tied together with rope. High-speed digital cameras were set in order to record the kinematics of the dummies during the collisions. The impact speed was 40km/h, and the impact location was the center of the vehicle.

Figure 9 shows the test results of the dummies' head and chest trajectories, both with and without the hood lift device operation.

Large differences in head and chest trajectories against the vehicle were not seen when comparing results with and without hood lift device operation. The hood lift actuator operated approximately 15ms after collision, and the time until the hood to be completely lifted was approximately 45ms.

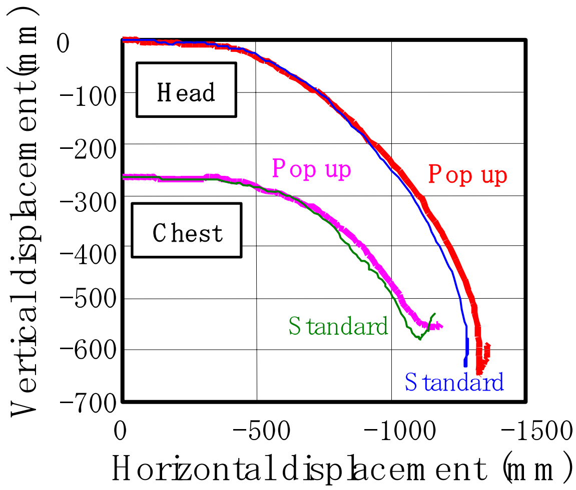

Figure 9. Head and chest trajectories with pop up hood compared to standard hood.

Figure 10 shows the dummy's resultant head speed against the vehicle, both with and without the hood lift device operation. The head speed rises from approximately 70ms, when the head starts to swing. The resultant head speed starts to lower from approximately 120ms when the shoulder and hood contact. The time of head contact with the hood was approximately 130ms.

It was confirmed that this system supports the hood up during the dummy's torso impacts the vehicle, until its head impacts with the hood.

Large difference in head speed against the vehicle was not seen when comparing results with and without hood lift device operation.

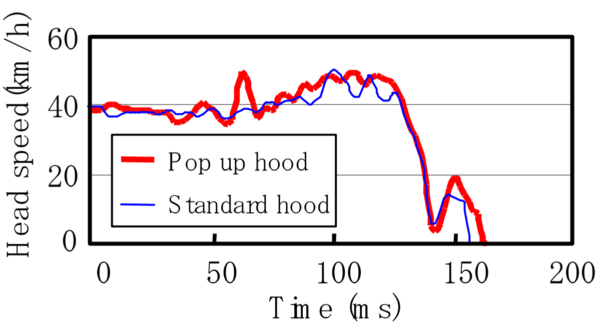

Figure 10. Head resultant speed.

Table 2 gives the wrap around distance (WAD), the speed at which the head impacts the hood, and the HIC value, both with and without the hood lift device operation.

Table2.
Test results of pedestrian dummy impact with pop up hood compared to standard hood.

	WAD	Head impact speed	HIC
Pop up hood	1910mm	34km/h	926
Standard hood	1910mm	35km/h	1353

Comparing the test results with the hood lift device operation and without its operation, the wrap around distance was the same. At the moment of head-hood contact, there were no great differences in head impact speeds.

There was an approximately 30% reduction in HIC values with the use of the pop-up hood system.

It is believed that increasing the space between the hood and the hard components under the hood, by lifting the hood, helps reduce the severity of the head contact with the hard components under the hood, thereby reducing HIC values.

CONCLUSIONS

C6Y's head contact time with the hood was determined through simulation, and a target device operation time was set at 60ms or less.

Giving due consideration to the sensing time, the target deployment time was set at 30ms or less in this study.

A pop-up hood system was developed, composed of bumper sensors, link type hinges, and pyro-actuators. The device operation was confirmed through tests.

Furthermore, pedestrian dummy tests were conducted, confirming the effect of the hood lift operation on dummy kinematics and on injury values.

The findings are as follows:

1) The hood lift time was within the targeted time of 30ms. With the adoption of pyro-actuators, a rapid operation speed was actualized.

2) Comparing the test results with and without the hood lift device operation, there were no great differences in dummy trajectory, or in head impact speed. And the wrap around distance was the same.

3) The effect of the pop-up hood system was a HIC reduction of approximately 30%, and this was confirmed through pedestrian dummy tests.

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